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Perceptions of climate change variability and adaptation strategies on smallholder dairy farming systems: Insights from Siaya Sub-County of Western Kenya

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ABSTRACT

Climate change and variability is bound to impact Smallholder Dairy Farming Systems as a result of overreliance on rainfed fodder production; yet climate models project increased frequencies of droughts that have a bearing on the Length of Growing Period. Similarly higher environmental temperatures are partly attributed to biome-range shifts, implying a likelihood of emerging and re-emergence of livestock and fodder diseases and pests. Nonetheless not much is documented of perceptions and adaptation strategies employed by Smallholder Dairy Farming Systems geared towards resilience to climatie shocks. By employing a mixed method approach that included household surveys, focused group discussions and statistical data analysis using SPSS package, this study aimed to bridge some of the existing gaps in adaptation strategies on Smallholder Dairy Farming Systems in Siaya Sub-County of Western Kenya. Survey results obtained from 100 households and Focused Group Discussions revealed that the climate of the study location was perceived to have changed, with droughts singled out as the most frequent. These perceptions were consistent with long-term climate data analysis which affirmed that all seasons, i.e. MAM, JJA, and DJF with the exception of SON showed longterm drying trends. Similarly, environmental temperature showed upward trends in both maximum and minimum temperatures that were perceived to be the cause of proliferation of noxious weeds previously associated with hotter areas of the Sub-County. Typologies of adaptation strategies used in the study showed that adaptation options were limited since these were viewed through a narrow lens of disease control by regular spraying and maize stovers as supplementary livestock feed during fodder dearth periods. This study recommends that besides awareness creation of adverse impacts of climate change and variability, facilitation for ease of access to technologies that ameliorate its adverse effects ought to be put in place. Additionally, empirical studies on consequences of biome range shifts on pasture and fodder productivity, and future possible impacts of diseases on *Bos taurus* breeds associated with climate change and variability should be undertaken.

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1. Introduction

Climate change and variability (CCV) is one of the greatest challenges to Smallholder Dairy Farming Systems (SDFS), yet demand for Animal Source Foods (ASF) is projected to rise (FAO, 2011a) due to population growth, urban migration, and increased spending in developing countries as a result of improved incomes (Giovannucci et al., 2012). In Kenya, SDFS form one of the most important livelihood strategies amongst rural communities. It dominates the national milk sector, accounting for 80% of total milk produced and with a corresponding agricultural Gross Domestic Product (GDP) of 30% (FAO, 2011b). Factors singled out that negatively impact SDFS are: poor agronomic practices; reduced fodder and crop residue yields; land fragmentation; declining soil fertility; increased incidences of pests and diseases; lack of capital (to aid adaptation measures); socio-cultural and religious factors; levels of infrastructural development; facilities that include ready markets, institutions, technology; early warning and early action systems for timely dissemination of weather and climate information (Thornton et al., 2007; FAO, 2011b, 2014; J.R. Beddington et al., 2012; J. Beddington et al., 2012; Jayne and Muyanga, 2012; Antwi-Agyei et al., 2013).

SDFS characterised by mixed farming (crop and livestock production) and dominated by *Bos taurus* (exotic cattle) breeds for milk production is one of several livestock production systems in East Africa (van den Bossche and Coetzer, 2008; Kabirizi et al., 2014; Thornton and Herrero, 2014) that is highly susceptible to CCV (Kotir, 2011) as a result of rising temperatures, frequent droughts, and intense floods leading to increased production pressure further aggravating food insecurity (Kotir, 2011; World Bank, 2013; FAO, 2014). Additionally, results from regional climate models predict that more areas in SSA will be more arid in future further impacting rural livelihoods through altered Length of Growing Period (LGP) (Kotir, 2011; Thornton et al., 2014) which has a bearing on availability of fodder quantity and quality alongside crop residues used as supplementary feeds in B. taurus dominated systems (Knox et al., 2012; FAO, 2011b, 2014; Kabirizi et al., 2014; Niang et al., 2014; Thornton and Herrero, 2014). Reduced LGP is likely to trigger shifts from SDFS (mixed crop and livestock production) to more dominant livestock based production systems with high probability of offsetting the food balance due to increased frequency of failure of traditionally grown crops (Anyamba et al., 2014; Niang et al., 2014). This scenario is bound to lead to dynamic complexities and farming systems where SDFS test and adopt both indigenous methods based on perceptions of CCV and modern technologies that work best for increased productivity (Mertz et al., 2009; Below et al., 2014).

According to Giovannucci et al. (2012), rural-urban migration in Sub Saharan Africa (SSA) is associated with CCV due to dwindling farm yields and prompts rural based populations to seek alternative livelihoods (FAO, 2015). This directly impacts labour availability, resulting to women and the elderly in rural areas taking on additional and non-traditional gendered roles which include offering social protection (WHO, 2011) thus increasing exposure to climate related risks that further affect productivity (Beddington et al., 2012a; Giovannucci et al., 2012; FAO, 2015). Production is further compounded by limited access and control over factors of production (land, credit, assets, knowledge, technology and efficient extension services) (Giovannucci et al., 2012; Antwi-Agyei et al., 2013) that aid in adaptation strategies by women who own and manage most SDFS (FAO, 2015). Yet SDFS, as one of the livestock production systems, is expected to play a major role in meeting part of the future Animal Source Foods (ASF) demand (Giovannucci et al., 2012; Porter, 2014).

Adaptation to CCV is based on experience arising from the length of years of practice and entails a two-step process since the adopter has first to perceive extreme climatic and weather events which trigger adaptation strategies that ameliorate adverse effects of CCV (Adger et al., 2009; Deressa et al., 2011). Other factors that affect adaptation strategies include: access to climate and weather information; awareness of CCV; technology; education; gender and age; resource endowment; institutional and environmental factors (Cornforth, 2011; Deressa, 2011; Milfont, 2012). Adaptation responses vary across regions and are influenced by the capacity of a community's ability to perceive climatic changes and institute strategies that effectively counter associated negative impacts for sustained production (Codjoe and Owusu, 2011). According to IPCC (2014), perceptions of, and adaptation to CCV are place and context specific and no single approach employed appropriately reduces risks across board. As such various methods with deviants from the long established traditional technological pathways for tackling CCV have since emerged to the extent that local knowledge systems comprising holistic views of the environment are considered key resources in adapting to a changing climate (IPCC, 2014; Porter et al., 2014). Further local knowledge systems driven by perceptions to CCV are not consistently used together with traditionally long-established methods to ameliorate negative effects of CCV and this could affect implementation of adaptation strategies (IPCC, 2014; Porter et al., 2014). Rapid CCV can also render local knowledge systems ineffective therefore compromising adaptive capacities with dire consequences on resilience of SDFS (Porter et al., 2014) since farmers make cropping decisions based on local perceptions to climate change but are unable to link long-term changes to CCV due to factors such as levels of education and performance of agro-economic crops that comprise key livelihoods (Rao et al., 2011).

The objective of this study is to identify smallholder dairy farmers perceptions of CCV and adaptation strategies deployed in SDFS in North Alego Location of Siaya Sub- County in Western Kenya, with the aim of guiding policy-makers on ways to promote adaptation strategies for resilient farming systems.

2. Materials and methods

2.1. Study area and survey design

This study was conducted between 2nd September 2015 and 16th November 2015 in Siaya Sub-County of Western Kenya. Siaya Sub-County (Fig. 1) covers an area of 605.68 km^2 and lies approximately between latitudes 0°26′ South to 0°18′ North and longitudes 33°58–34°33′ East (GOK, 2013). The annual rainfall pattern in the study area is bi-modal, with “long rains” occurring between March

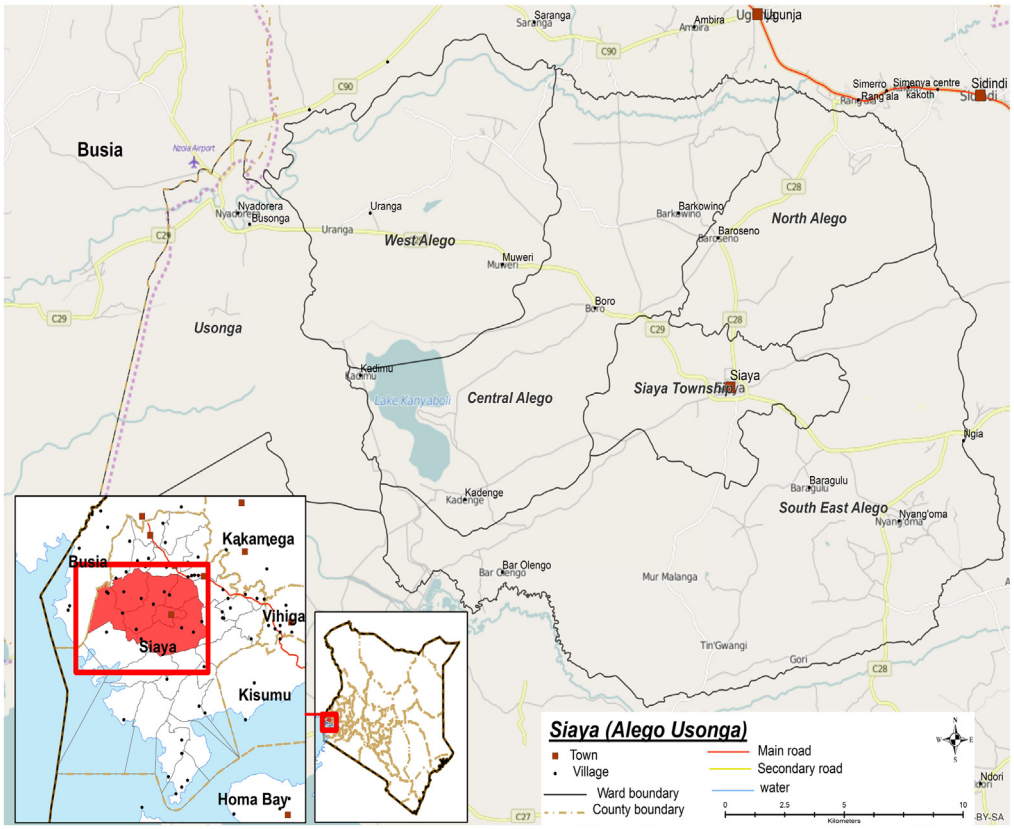

Fig. 1. Map of Siaya Sub-County.

and June and "short rains" between September and December (MOA, 2009). Temperatures vary with altitude but on average range from 16.3 °C to 29.1 °C lower areas of the Sub-County recording the highest temperatures. Humidity is relatively high with mean evaporation ranges of 1800 mm to 2200 mm per annum (GOK, 2013). Agricultural activities consisting of small scale rainfed farming are carried out on approximately carried out on approximately 47,800 Ha of arable land (Oganyo et al., 2016) with maize, sorghum, millet, beans, cowpeas, cassava, sweet potatoes, groundnuts and finger millet being cultivated on subsistence basis, though sugarcane, cotton, rice and groundnuts are considered as the major cash crops (GOK, 2013). Common livestock enterprises include exotic and indigenous cattle breeds, sheep, goats, dairy goats, beekeeping, pigs and indigenous poultry; but the dairy cattle density is low making only 10% of the total county cattle herd (GOK, 2013). The low dairy cattle density is consistent with the national data where in 2007 the former Nyanza province accounted for 5.9% of the total number of dairy cows nationally, and only 1.64% when the *B. indicus* (indigenous) breeds were considered (FAO, 2011a).

Several rivers form the drainage system into Lake Victoria with rivers Yala and Nzoia, alongside major tributaries (Huro, Akala North, Nyamonye, Woroya, Dande and Seme Awach) (GOK, 2013). There are also Lake Victoria satellite lakes (Lake Kanyaboli and Lake Sare), as well as natural springs (common in areas bordering Gem sub-county), and man-made dams and water pans (GOK, 2013). The groundwater potential for shallow wells and deep boreholes is high though this diminishes towards lower regions where aquifers have high salinity, posing irrigation challenges in a region of the Sub-County that experiences water scarcity the most (GOK, 2013).

Data used in this study was collected from North Alego Location of Siaya Sub-County. The study adopted a methodology that comprised qualitative and quantitative research (mixed) methods. Qualitative methods were used to gather information through participatory tools that comprised seasonal calendars, transect walks, Focused Group Discussions (FGDs) and key informants interviews. FGDs were used to draw historical profiles based on recall questions of perceived major climatic trends that was compared with long-term proxy climate data downloaded from TAMSAT (Map Coordinate, Latitude-0.060287; Longitude- 34.288296). Proxy satellite data has in the past been used in regions where long-term climate data is unavailable due to deterioration of ground observation stations (Novella and Thiaw, 2013; Maidment et al., 2015).

Structured questionnaires incorporating recall questions were administered to 100 smallholder dairy farmers who were purposively sampled to generate quantitative data that was analysed using Statistical Package for Social Sciences (SPSS) (Pallant, 2005). These results are presented using simple descriptive statistics that include chi square (χ^2) tests, tables, percentages, and graphs. A binomial logistic regression model was also run to check for farmer perceptions on the effects of invasive plants, vectors (ticks, tsetse and biting flies), slurry management, increased temperatures, drought and floods on prevalence of livestock disease incidences on SDFS. Similarly, correlation analysis was used to determine whether there were any relationships between the study variables.

Table 1
Cross tabulation of age group and education levels.

Age Group	Education Level (%)						Total (%)
	No Education	Primary School	Secondary School	High School	Middle Level College	University Level	
26–35	0	6	0	0	1	0	7
36–45	1	10	3	0	0	0	14
46–55	4	16	7	1	3	3	34
56–65	5	15	3	0	3	3	29
> 66 years	3	8	3	0	1	1	16
Total	13	55	16	1	8	7	100

3. Results and discussions

3.1. Household characteristics of SDFS farmers

Household (HH) questionnaire data analysis revealed that 71% of SDFS respondents were female while 21% were male which is consistent with observations made by WHO (2011) and FAO (2015) that besides performing other household chores that increased their vulnerabilities, women own most of SDFS and are engaged in the bulk of agricultural activities. In terms of age, 79% of the respondents were 46 years old and above; of these, 34% were between 46 and 55 years old. This has implications on productivity since SDFS is labour intensive and requires a higher degree of versatility in terms of farm operations. Further, 55% of the respondents had at least 7 years of basic education while 13% had no formal education. Cross tabulation of age groups and education levels showed that none of the respondents in the most active age bracket of 45 years and below (26 years) (Table 1) had university education while those with university education comprised only 7% spread over other age categories (*ibid*). One possible explanation for this trend could be lack of employment opportunities in the study location leading to migration of the young and educated population to urban settings in search of alternative livelihoods. Education levels play a major role in adoption of technologies (Giovannucci et al., 2012) that ameliorate adverse effects of CCV through fast tracking of adoption of adaptation strategies based on perceptions and climate risk related information. It aids in acquiring knowledge and skills since affected HH members are able to read and understand key points from a wide range of climate change and risk resources that could trigger adaptation responses, besides other channels that include local knowledge as an effective medium of learning for those with low education levels.

Further, 64% of Households (HHs) comprised between 4 and 7 persons, followed by 8–10 persons at 18%. Those HH comprising 1–3 and over 10 persons each were 9%. Fifty nine percent (59%) of respondents lived in semi-permanent structures, 32% stayed in permanent houses while 9% lived in grass-thatched houses. Additionally, a majority (54%) of the respondents relied on rivers as the main source of water, 36% on shallow wells while 10% depended on piped water whose flow was reported to be erratic hence unreliable. These findings have a bearing on living conditions of the study sample household members since the type of housing in a locality reflects the economic status of the resident population. The type of roofing structures can influence adoption of strategies that increase water harvesting to cater for scarcities during prolonged dry spells as various climate models predict that drought events will be more frequent (ICPAC, 2016). It was observed that some households practiced rain water harvesting using roof catchments but their storage capacities were low and hardly sufficient for domestic use, let alone dairy production. It was further discerned that 47% of respondents had practiced SDFS for a period ranging from 6 to 10 years, 9% for a period of 11–15 years while a similar number (9%) had practiced for 16 years and more. This translated to a total of 65% of active smallholder dairy farmers with 6 or more years experience; these were able to articulate views on major climatic events and trends lending more credence to perceptions and adaptation strategies by SDFS farmers.

An analysis of labour availability revealed that 75% of SDFS relied on HH labour which fluctuated periodically more so in HHs that comprised members of school going age or engaged in other off-farm production activities. Such a fluid labour situation can limit productivity levels as SDFS is labour intensive implying that irregular supply of labour can result in low performance since the nature of activities (fodder management, feeding, milking and general hygiene) require consistency in execution. It was also found that 85% of the respondents used firewood as a major source of cooking of which 58% lacked energy-saving cooking devices signifying use of more quantities of firewood during meal preparation times. This posses a higher risk of environmental degradation through deforestation that in most instances is a catalyst of soil erosion with implications on soil fertility hence fodder productivity. Further, 39% of the HHs used kerosene as a major source of lighting while the remainder (71%) used clean sources of energy comprising solar lamps (36%), and electricity (35%) which is a pointer towards good adaptation practices in energy use efficiency. It was further observed that none of the HHs managed livestock slurry under anaerobic conditions for conversion of methane (CH_4) to carbon dioxide (CO_2) which has a lower global warming potential hence all HHs were net emitters of GHGs resulting to a large carbon footprint.

3.2. SDFS farmers perceptions of droughts and floods

Results from FGDs and Key Informants (KIs) interviews revealed that drought incidences (expressed as prolonged dry spells) had increased, with drying of rivers that were once perennial singled out as one of the major indicators. From the FGDs, it was ascertained that due to frequent droughts (prolonged dry spells), provisioning services of riverine ecosystems had diminished; participants

indicated that they used to rely on rivers and swamps for provisioning services (fish, water and livestock licks) unlike today. The decline in ecosystem goods and services was reported to exert more strain on vulnerable HHs due to diminished access to alternative sources of ASF. Closely associated with droughts were changes in vegetation cover since it emerged from discussions that majority of indigenous trees that grew in relatively wet patches (riparian areas) are now hard to come by, a phenomenon attributed to lowering of the water table due to reduced recharge by green water. Indigenous trees that were singled out as having been affected by CCV were *Ficus thorningi* (pocho) and *Ficus cycomorus* (ngowo) which, according to members of the FGD served as indicators of shallow acquifers. This view was premised on observations that exploitation of underground water where these trees grew was easy in times of extreme water scarcity implying a high water table.

Besides CCV, other causes perceived to be attributed to indigenous tree cover decline leading to enhanced biophysical vulnerabilities were; felling of trees for timber, charcoal making, house construction, firewood, cultural practices (*magenga* – a tradition where bonfires are lit during night vigils at funerals), and for fires used to ward off livestock related pests. While the frequency of drought incidences was observed to be increasing, flood occurrences was reported to be on decline though their devastating effects are now more pronounced when taken as proxy of crop and livestock losses, and livestock displacement. Livestock deaths were attributed to lack of fodder due to prolonged flooding of pastures, and drowning especially for small ruminants and poultry. Similarly, waterborne disease outbreaks, specifically diarrhoea, dysentery and cholera, were attributed to pit latrines collapsing or overflowing leading to contamination of fresh water sources. Upsurges in malarial fever cases were linked to favourable environmental conditions for breeding of the *Anopheles* mosquitoes. Malnutrition as a result of inadequate food due to crop damage was reported to be common following periods of prolonged floods. According to one of the Key Informants (KIs), mitigation costs related to drought and flood damages are on the rise due to their increased severity. The severity of extreme climate events was reported to be trapping more HHs in the poverty cycle due to insufficient time to recover and recoup their assets before the onset of the next extreme climate event implying shortening of return periods. It was further discerned from FGDs that disease vector densities (tsetse flies) increased during flood periods meaning that floods led to favourable conditions for proliferation of vectors and vector borne diseases.

From data analysis and observations, it emerged that, farmer perceptions to drought and floods mirrored recorded incidences not in magnitude but in trend. For instance, GOK (2009) noted the periods 1961–1962 and 1997–1998 as having the worst flood events, with the latter covering a wider area, being relentless in nature and most intense. Other years that experienced major floods include 1937, 1947, 1951, 1957–1958 and 1978 *(ibid*). The reported increase in the frequency of droughts by the FGDs corresponds well with observations made from several studies (cf. Williams and Funk, 2011; Shongwe et al., 2011; Shiferaw et al., 2014; Kalungu et al., 2013; Salazar-Espinoza et al., 2015) implying shorter drought return periods that are further bound to impact SDFS in terms of LGP coupled with diminishing availability of both green and blue water that is crucial in all livestock production systems.

3.3. SDFS farmers perceptions of rainfall

Focus group discussions revealed that the intensity and pattern of rains during the main rainfall seasons had changed and that it exhibited a high degree of irregularity, leading to frequent food and fodder crop failure. More discussions with KIs affirmed that rainfall patterns had changed to the extent that short rains were now more reliable as reflected through lower crop failure rates on farms compared to the long rains seasons. However, results obtained from HHs perceptions of rainfall in relation to categorical variables (increasing, decreasing, fluctuating, no change and unpredictable) were significant ($\chi^2 = 12.029$, $p = 0.017$), denoting varied responses amongst SDFS. Such differences in perceptions occurring in a homogenous sample could play a role in adaptation strategies and adoption of adaptation rates as wide variations in perceptions can have implications on long-term adaptation processes. For instance, while the study sample agreed that the climate of the area had changed inter-decadal cropping calendars showed that SDFS still retained their traditional planting dates which could lead to higher risks of crop and fodder failure.

Farmer and KIs perceptions of rainfall and rainfall patterns compared well with rainfall data which indicated a long-term drying trend for annual cumulative rainfall, as well as for the seasons March-April-May (MAM – wet season) June-July-August (JJA – cool and dry season), December-January-February (DJF – hot and dry season) (Figs. 2–4 and 5). However, the September-October-November (SON – wet season) season was an exception as it exhibited a long-term wetting (Fig. 6). These observations were further confirmed by regression coefficients (*B*) for rainfall trends that were significantly different from zero (0) (p-value < 0.01) denoting high seasonal variations in rainfall (Tables 2 and 3).

Comparisons of inter-decal standard deviations were insignificant ($p = 0.397$) but analysis of total annual rainfall revealed a steady decline that conformed to the perception that there has been a long-term decrease in total annual rainfall (Fig. 2). June rainfall contributed positively to the MAM since it considerably increased the amounts of precipitation received. SON/D recorded lower rainfall compared to MAM and MAM/J but the trend has been one of increasing rainfall (Fig. 6) and confirms observations made by KIs that short rains season has become wetter. Likewise, and except for the 1993–1997 period, SON/D had the highest pentad standard deviation for (1983–2015) compared to the rest of the seasons (DJF, MAM, MAM/J, and JJA) implying high rainfall variability. When rainfall data was subjected to correlation coefficient (r) analysis it was deduced that total annual rainfall was strongly positively correlated ($r > 0.5$) to JJA and SON/D but weakly positively correlated ($r = 0.494$) to MAM an indication that MAM rainfall contribution to crop and fodder production is on the wane.

3.4. SDFS Perceptions of temperature trends

There was a strong consensus amongst FGD participants that temperatures of the study area had increased, and was based on observation of emergence of invasive noxious weeds that traditionally occupied areas that were hotter and drier than the study

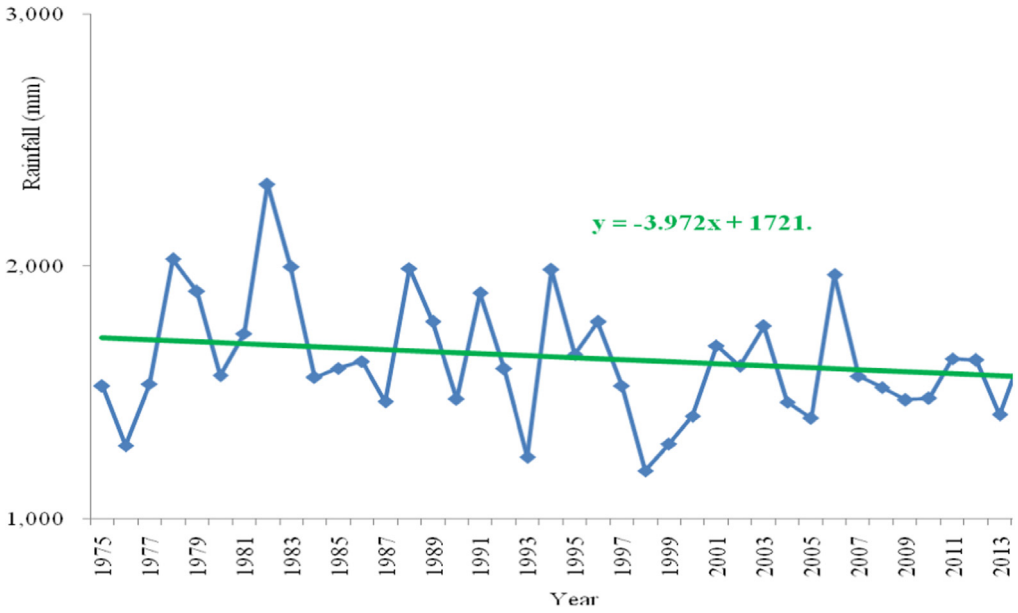

Fig. 2. Longterm annual rainfall for Siaya Sub-County.

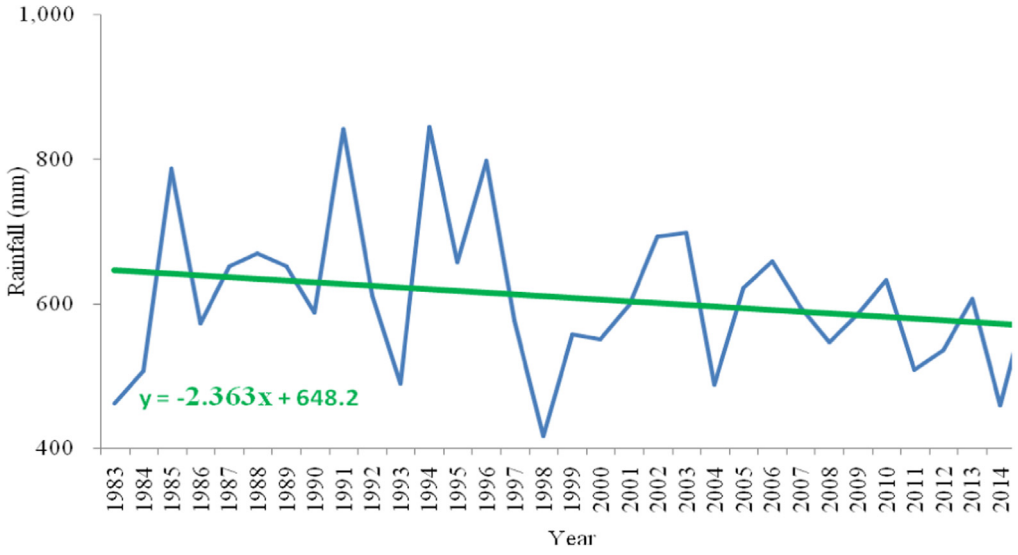

Fig. 3. Longterm MAM rainfall for Siaya Sub-County.

location. The specific weeds singled out were *Mimosa pudica* (siro-siro), *Lantana camara* (obengele), *Striga hermonthica* (hayongo) and *Occimum basilicum.* For example, it emerged from discussions that *M. pudica* (siro-siro), an endemic species of the lower and drier regions of the Sub-County, characterised by high temperatures most of the year is now common in the study location that was once devoid of it since the latter area had relatively cooler temperatures. According to FGD participants, *M. pudica* is a thorny non-livestock fodder that smothers and kills grasses due to its growth habit while its sharp thorns inhibit grazing of understory grasses further reducing fodder availability both for grazing and as standing hay that is an important element in the cut and carry system of SDFS. Similarly farmers associated increased weed population (invasive ruderal species) to increased temperature amongst other climate change factors. L. *camara, O. basilicum* and *Stachytarpheta* sp. (blue porterweed) were reported as invasive ruderal plant species that showed signs of permanently establishing themselves on abandoned farmlands and disturbed sites. This observation correlated well with HH survey result as perceptions of temperature trends were significant ($\chi^2 = 26.750$, $p = 0.000$).

Due to lack of data from ground-based meteorological stations, minimum and maximum temperature data for Kisumu Station was used as a proxy for long-term temperature trends for ease of comparison with perceptions of temperature variations amongst FGD participants and results from HH surveys. This approach was tenable since the spatial temperature variations between the study site

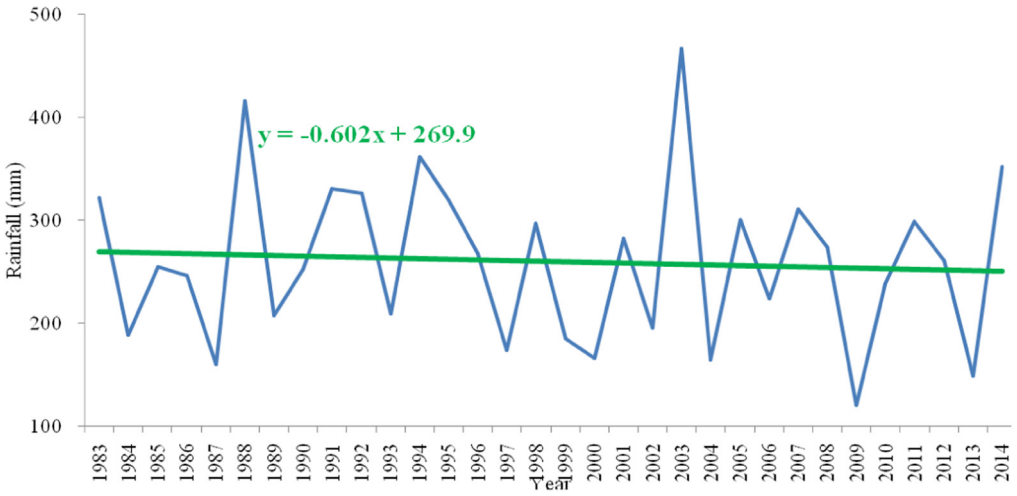

Fig. 4. Longterm JJA rainfall for Siaya Sub-County.

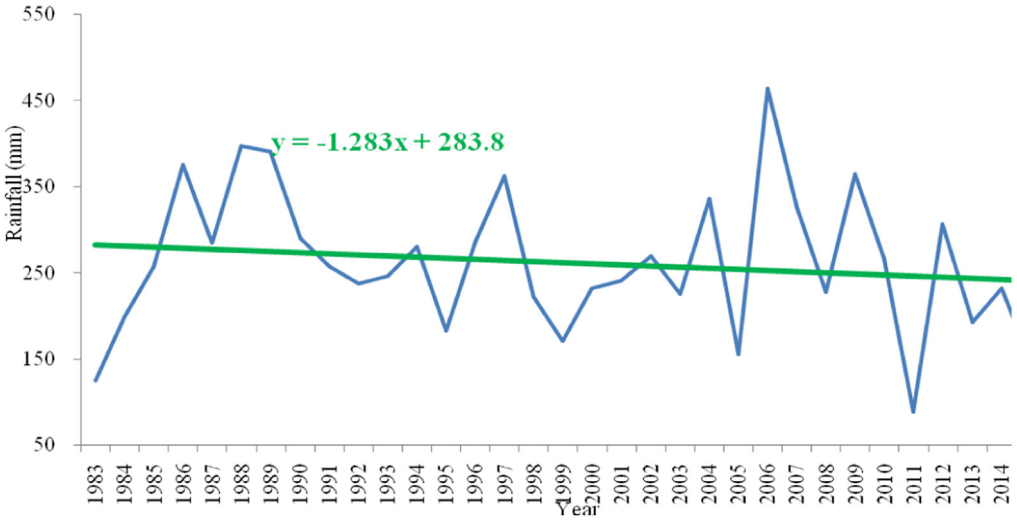

Fig. 5. Longterm DJF rainfall for Siaya Sub-County.

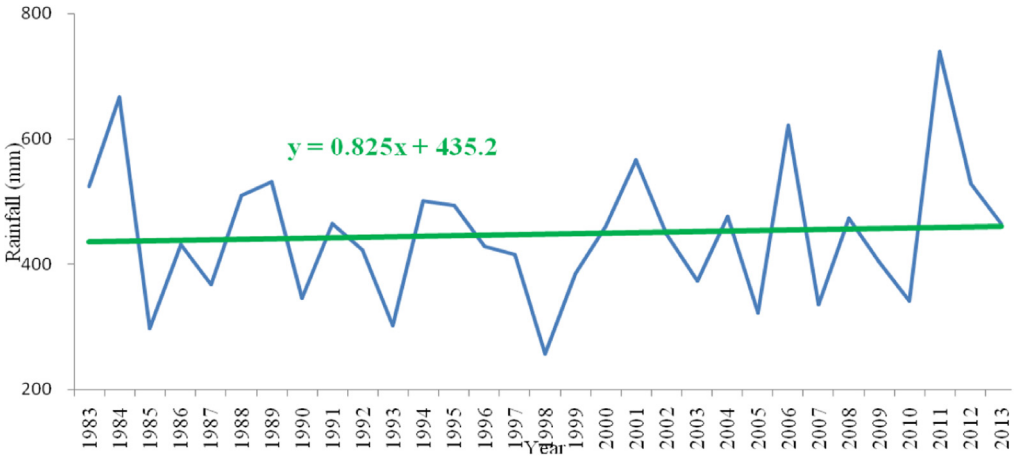

Fig. 6. Long-term SON rainfall for Siaya County.

Table 2
One sample student *t*-test for seasonal trends (MAM, JJA, SON and DJF).

One-Sample Test *(B ≠ 0)*						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
MAM	32.321	32	0.000	704.72727	660.3145	749.1401
DJF	17.877	32	0.000	262.03030	232.1736	291.8870
JJA	18.055	32	0.000	265.03030	235.1299	294.9307
SON	22.384	32	0.000	461.66667	419.6553	503.6780

Table 3
One sample student *t*-test for annual cumulative rainfall.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Annual cumulative	43.385	40	0.000	1638.43902	1562.1135	1714.7645

and that of Kisumu station are minimal as both areas experience a similar climate regime (KMD, 2011). Hence according to KMD (2011, p. 54), there has been a long-term increase in both maximum and minimum temperatures overtime.

Invasive noxious weeds singled out by FGD participants are bio-proxy indicators of global warming attributed to biome-range shifts (cf. Moorhouse and Macdonald, 2015). A transect walk led to observations that L. Camara in some areas had formed single species ruderal communities implying a shift in ecosystem composition and its provisioning services since dense L. *Camara* stands smother understory grasses contributing to reduced fodder availability.

3.5. SDFS farmer perceptions of effects of temperature and rainfall on quantities of fodder

Farmer perceptions on quantities of fodder produced were varied though 94% concurred that temperature and rainfall had effects on feed availability for dairy cattle. Despite this, a high proportion of respondents differed on the effects of rainfall; on soil erosion, its duration, and temperature in relation to fodder production. This indicates that although farmers were aware of CCV impacts on SDFS, they were not able to differentiate or isolate the pathways through which the changes affected fodder production.

From the survey data, 99% of HHs perceived the quantity of fodder fed as having effects on milk yields though significant differences amongst the respondents on amounts of fodder fed in relation to milk yields existed. Reduced fodder fed significantly led to decreased milk yields ($p < 0.05$), however, increased fodder fed did not significantly lead to increased milk quantities and could be attributed to other factors such as fodder quality, ambient temperature and genetic makeup of the breeds reared. Acreage under Napier increased by 93% (2004–2014) while lower percentage increases were observed with respect to improved pastures, fodder legumes and natural pastures. Fodder trees increased by 50.7% over the same period, suggesting an adaptation strategy to perennial fodder and fuel wood scarcity.

3.6. SDFS farmers perceptions of disease challenges due to CCV

Farmers in the study location faced a myriad of disease challenges as 79% of the HHs indicated that livestock disease incidences were on the increase with 77% having had their livestock affected by vector borne diseases. Fifty eight percent (58%) of the HHs attributed livestock vector borne diseases to a combination of ticks, biting and tsetse flies. Respondents indicated that a high disease burden occurred during periods of high vector build-up related to: increased incidences of drought (47%); increased flood events (42%); high temperatures (39%); suitable vector habitats due to invasive ruderal plant species (34%); poor slurry management leading to suitable breeding grounds for disease vectors (32%).

Results from a binary logistic regression model showed that invasive plant species, temperature, floods, frequency of droughts, and poor waste management had significant effect on incidences of livestock diseases ($p < 0.05$) (Table 4). An increase in invasive plant species created suitable vector habitats ($p = 0.045$). Increased temperatures ($p = 0.021$), floods ($p = 0.037$) and droughts ($p = 0.032$) led to vector build-up while poor waste management ($p = 0.027$) contributed to suitable vector breeding sites that increased incidences of livestock diseases.

Table 4
Results of binary regression model.

Variables in the Equation		B	S.E.	Wald	df	Sig.	Exp(B)	95% C. I. for EXP(B)	
								Lower	Upper
Step 1[a]	Poor Waste Mgt Suitable Vector Breeding Sites	3.109	1.410	4.863	1	0.027	22.401	1.413	355.072
	Drought Vector Build-up	1.185	0.992	1.427	1	0.032	3.270	0.468	22.844
	Flood incidences Vector Build-up	3.344	1.604	4.348	1	0.037	28.333	1.222	656.789
	Increasing Temperature Vector Build-up	3.396	1.476	5.290	1	0.021	29.837	1.652	538.886
	Invasive Plant Species Suitable Vector Habitats	−0.246	1.260	0.038	1	0.045	0.782	0.066	9.238
	Constant	−8.987	5.261	13.027	1	0.000	0.000		

[a] Variable(s) entered on step 1: Poor Waste management, Drought, Flood incidences, Increased Temperature, Invasive Plant Species.

Similarly, 78% of respondents attributed decreased milk yields to drought. Vector populations in relation to vector borne diseases were positively correlated to decreased milk yields. A logistic regression model indicated that variation in tsetse and tick population had significant effect on the prevalence of vectors ($p < 0.05$). Moreover, an increase in the population of tsetse flies ($p = 0.002$) increased the prevalence of vectors on the farm by a higher amount compared to an increase in tick population ($p = 0.012$). Presence of biting flies ($p = 0.133$) did not significantly affect presence of vectors but this did not imply that they had no implication on the prevalence of livestock diseases.

3.7. Adaptation strategies

Farmers in the study location undertook various adaptation strategies to reduce adverse impacts of CCV with mixed outcomes since some strategies were observed to have led to maladaptation. At the community level adaptation measures employed during food crop dearth periods included use of: root crops (cassava and sweet potatoes); preserved vegetables; wild vegetables (for example *Basella alba* (Nderema), *Ludwigia stoloniferia* (Nyasigumba), *Acalypha volkensii* (Dindi), *Asystasia mysorensis* (Atipa) *Sesamum angustifolium* (Onyulo); preserved mushrooms; dependency on extended families for cash handouts especially for households with family members that had migrated to other regions in search of alternative livelihoods. However, during the FGD interactions it was deduced that the use of wild vegetables was on decline due to opening up of virgin land that served as a source and reservoir of wild vegetable species, invasion of the natural habitat by noxious weeds, and breakdown of traditional knowledge systems due to out-migration. Additionally it was reported that food was imported from areas with surplus by well-off families during famines, while the poor and vulnerable households relied on food handouts from various relief agencies. This observation is consistent with findings by Runguma (2014; p. 147).

Major foods brought in included cereals and pulses alongside root crops (cassava and potatoes) and bananas as planting materials from as far as Uganda, though these were attributed to emergence of new plant diseases that exacerbated vulnerabilities of people reliant on root crops as a major source of food and income. For instance, black sigatoka of the *Musa spp* (Banana), cassava mosaic of *Manihot esculenta*, Napier stunt and snow mold are some of the diseases that were perceived to have been introduced in the area through food importation during periods of scarcity and are currently positively linked with low food crop and fodder productivity. Though this coping strategy helped reduce the severity of climatic shocks it led to maladaptation since lack of phytosanitary measures resulted in emergence of new plant and fodder diseases.

Based on types of adaptation strategies on SDFS (Table 5), HH survey results showed that while a large and wide menu of adaptation strategies exists, not all SDFS farmers have adapted them in tandem to perceived adverse effects of CCV. This led to a supposition that SDFS farmers in the study area view existing opportunities and adaptation strategies through a narrow lens. For instance, the most common adaptation strategies employed were regular spraying of livestock to control disease vector populations (95%), regular vaccinations against notifiable diseases (86%) and use of maize stover for supplementary feeding (70%) which, is an indication that SDFS face a heavy livestock disease burden mediated through disease vectors such as ticks, tsetse and biting flies (*tabanids and stomoxys*) and fodder scarcity. This view is reinforced from the observation that 73% of HH indicated that they did not manage livestock waste (slurry) which could lead to creation of suitable breeding grounds for debilitating vectors that contribute to livestock disease flare-ups. This further conforms to results of the earlier model (Table 4) that a slight increase in tsetse density influences the presence of other vectors at higher scales while a moderate increase in tick population has a similar effect but the presence of biting flies has no effect on the prevalence of other vectors. On the other hand, overreliance on maize stovers is an indication that SDFS productivity is limited by none-availability of high quality feeds reflected by the absence of fodder conservation practices, since no farm surveyed had fodder preservation structures such as silage pits, hay barns, tube silage, and maize stover stores. It was also observed that equipment used in acaricide delivery for control of ecto-parasites were the non-recommended types and could lead to maladaptation since inefficient delivery could lead to vectors developing resistance to acaricides in future.

Further, stovers are low in protein content, high in fibre, and the absence of attempts to improve its quality prior to feeding is an indication that it is solely used for maintenance purposes. The least applied adaptation strategies ranged from modification of dairy units for temperature regulation (5%) to establishment of improved pasture (37%) (Table 5). There was no recorded use of slurry as an alternative source of energy for lighting and cooking. The least utilized adaptation strategies that could further contribute to creation of resilient systems were those that are technocentric since; such strategies require adequate literacy levels to enable SDFS to

Table 5
Types of adaptation strategies.

Adaptation Strategy (N = 100)	Yes (%)
Use of slurry as an alternative source of energy (methane CH_4)	0
Modification of dairy unit for temperature regulation	5
Production of fodder under irrigation	13
Shift to higher yielding fodder varieties	15
Bush clearing to alter suitable breeding habitats for disease vectors)	24
Cross breeding of dairy cattle (off-springs tolerant to increased temperatures)	27
Establishment of Napier under tumbukiza "Zai pits"	32
Practice soil conservation measures	33
Establishment of improved grass species (hay production)	37
Sinking of shallow wells for provision of water all year round	40
Planting of fodder trees for additional fodder and firewood	42
Introduction of new fodder varieties (flood, temperature and drought tolerant)	51
Planting of fodder crop along contours (soil erosion control)	54
Manure application on fodder fields (soil moisture retention, increase soil fertility)	55
Planting of Napier in furrows for water retention	61
Use of roof catchment for additional water supply	69
Use of maize stovers (supplementary feeding)	70
Regular vaccinations against common livestock diseases	86
Regular spraying against diseases vectors	95

rapidly grasp the guiding principles behind them, have relatively high cost implications, and need expert guidance hence the phrase by Giovannucci et al. (2012; P.38) "many new technologies are unknown, unaffordable, and inaccessible to smallholder farmers who form the majority of producers in most of Africa".

Absence of fodder processing technologies to improve feed quality before feeding for increased milk yields of *Bos taurus* breeds could be an indicator of inadequate extension services or lack of technical knowhow amongst extension providers. This arises from observation that there were no livestock farm structures such as hay barns, silo pits or silo stores for fodder conservation and use. Neither were there bio-gas plants for provision of clean energy amongst the study sample. Extension services are singled out as avenues for dissemination of technologies, market information, and linking of players in the dairy value chain and are recognized as an effective knowledge transfer mechanism (De Rosa et al., 2014; Mbo'o-Tchouawou and Colverson, 2014) for increased productivity of SDFS, high farm incomes and well-being.

To this effect, government run agencies are better placed to administer this service since non-state actors in the extension sector can only reach a limited number of the target clientele and are also constrained by overreliance on donor agencies for funding (Mbo'o-Tchouawou and Colverson, 2014). Owens et al. (2003) note that in Zimbabwe farms which accessed one to two extension services per annum realised a 15% increase in crop productivity hence supporting observations that frequent farm visits by extension agents could play a role in creation of resilient farming systems. In Kenya, extension services were devolved to county governments in line with the requirements of the Constitution of Kenya 2010; this poses risks to the stability and effectiveness of the extension services through, for instance, lack of adequate capacity, inadequate coordination, as well as disparate approaches and variable funding levels across the devolved governance units.

> *"We no longer visit farmers as often as we did before devolution. Our motorcycles are now old and frequently break down yet we are not facilitated to repair them on time. Also, issuance of fuel from the County Government is irregular leading to over reliance on NGO's working in our wards for facilitation but this is only whenever they have activities touching on livestock production. In times of emergencies we are left with no option but fuel our motorcycles and indirectly pass the cost to the farmer*" [One of the livestock extension officers, 30th October 2015].

This implies that SDFS located in areas of low NGO concentration are at a disadvantage and risk engaging in maladaptive practices due to infrequent interaction with extension officers.

3.8. Policy implications

Climate change and variability impacts SDFS by deepening food insecurity (Carabine et al., 2014; Porter et al., 2014) and thus adversely affects the livelihoods of vulnerable HHs. Since climate change impacts cut across sectors, there is need for the implementation of adaptation strategies that will enable affected communities to adjust to the current and future adverse effects of climate variability and change (IPCC et al., 2014). According to Eriksen et al. (2016) adaptation is a process where a community is facilitated to make decisions about its livelihoods with the aim of reducing vulnerabilities associated with CCV while at the same time taking into account then non-climatic stressors (skewed distribution of resource, access to factors of production and overall poverty status). It therefore requires charting of development pathways that steer away from Business As Usual (BAU) scenarios. For instance, the Kenya government has from time to time declared through public policies and Acts of Parliament its objectives and intentions of achieving and preserving national values and norms in the interest of its citizenry.

Provision of extension services aimed at achieving food security is one of such intentions which encompass provision of a public

good and service that would otherwise be underfunded and underprovided for by non-state actors; as it entails massive cash injections with no direct and tangible benefits in terms of accrued revenue and profits to the donor. Devolution of this service without tangible policy changes might therefore lead to low funding of extension services at the expense of sectors and services (construction of roads, dispensaries, classrooms etc.) that comprise low hanging fruits.

Some of the efforts put in place to address this and thus impacts of CCV include; the Climate Change Act (GOK, 2016a) which envisages formulation of a National Climate Change Action Plan (NCCAP) that brings onboard all sectors of the economy, The National Adaptation Plan (NAP) (GOK, 2016b), the National Climate Change Policy Framework (GOK, 2016c) and the Dairy NAMA (GOK, 2017). Implementation of highlighted policy documents is on going hence their contribution towards building resilience to CCV across sectors is not yet quantified, as reflected by the patchy and reactive responses to recent extreme climatic events in Kenya. A further look at the ongoing projects and initiatives under implementation by the Livestock Sub-Sector show that with the exception of the Dairy NAMA, there is overconcentration of efforts in Rangelands (GOK, 2016b). Besides, NAMAs are traditionally heavy on mitigation actions (Kojwang and Larwano, 2015), yet climate change without adaptation is projected to negatively impact SDFS at regional scales (IPCC et al., 2014). As a result, this could lead to a likelihood of increased maladaptation with more SDFS becoming vulnerable to severe impacts of CCV.

4. Conclusion

This paper has highlighted various ways SDFS farmers perceive and adapt to adverse effects of CCV and makes it clear that smallholder farmer perceptions are place and context specific where; experience, and age plays a key role in discerning environmental/climate change that in turn act as stimuli for adoption of a range of adaptation strategies. Despite this, there is evidence that SDFS perceptions relative to CCV aspects are varied across multiple scales and could play a role in the slow rates of adaptation strategies. This is due to different worldviews held by individuals in terms of cause-effect and the causal pathways. Further the study shows that the climate of the study location has changed as SDFS farmers' perceptions in terms of rainfall, temperatures, droughts and floods are congruent with long term climate records. However, despite a wide array of adaptation strategies, SDFS farmers view these options through a narrow lens of disease control, maize stover as a supplementary livestock feed, and importation of food crops during dearth periods that result in maladaptive practices. Such limited adaptation strategies are a pointer to low exposure to available adaptation options and could be a result of low education levels that act as barriers to adaptation. Lack of climate change adaptation expert advice to provide knowledge on adverse impacts of CCV and appropriate coping mechanisms can not as well be ruled out. Climate change centred policies therefore need to be put in place with emphasis on early warning and early action weather and climate dissemination information systems to assist in development of *ex-ante and ex-post* buffers to severe effects of climate change for resilience building. This study proposes that mechanisms that enable SDFS access technologies that work in ameliorating CCV impacts, besides awareness creation of its adverse effects, be put in place. Further, there is need for empirical studies on effects of biome-range shifts on pastures and fodder production together with possible future impacts of vector borne diseases on existing *Bos taurus* breeds in the study location.

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